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Supratentorial Dissection of the Human Brain for Neuroscientists

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ABSTRACT

Background: Recent clinical advancements, including brain imaging or target specific procedures, have increased the demand for a more advanced understanding of the structure of the brain. The need for a more sophisticated, functionally relevant understanding the structure of the brain has resulted in a surge of neuroanatomy dissection courses, including gross neuroanatomical observation, cross-sectioning, blunt dissection and various fiber dissection techniques. **Methods:** Sixteen (16) adult, formalin fixed cerebral hemispheres were included in this study. Surface anatomy, blunt dissection of the lateral ventricles, and cross-sectioning of the anterior portion of the hemisphere, was performed on all specimens. **Results:** A detailed, but simplified, protocol consisting of seven steps is proposed for the study of the supratentorial anatomy of the human brain. The first two steps promote an appreciation of the predominate structural pattern of the surface of the brain. Four distinct, consecutive dissection steps are recommended for the dissection of the ventricular system. Horizontal cross-sectioning of the anterior portion of the hemisphere is described in five sub-steps. **Conclusion:** Dissection methods described provides an appreciation of the predominate structural pattern of the surface of the brain, in relation to the deep the structures. This appreciation is gained through the step-by-step dissection of the ventricular system and cross-sections. In addition to understanding the surface-to-deep relationships, the hands-on practical study of the anatomy of brain as described herein, allows the observer to gain a true three-dimensional structural understanding of the human brain.

Keywords: *Neuroanatomy, Cross-Sections, Gyri, Sulci, Surface Anatomy, Supratentorial.*

INTRODUCTION

It is well acknowledged that the folding and invagination of the *cortex* allows for a significant increase in the surface area without increasing brain volume.[1] With the blunt dissection described below, the highly convoluted pattern of the cerebral sulci and gyri can be observed.

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Almost two-thirds of the cortex is hidden deep within the sulci. Unfolded, the cortex would cover a surface area of almost one square meter. Continuity between gyri is a general phenomenon across the entire hemisphere. This gyral continuum is an important feature for those studying the brain to grasp.

While sulcal anatomy varies considerably, including those that are long, short, continuous or interrupted, the major sulci are fairly constant and uninterrupted.[2] Sulci can be limited to the cortex (cortical sulci) or can be deep, extending through the entire depth of the hemisphere (fissures). According to the International Anatomical Terminology,[3] the major sulci and fissures serve to arbitrarily divide the brain into its primary lobes (frontal, parietal, occipital and temporal lobes) and functional regions. It is noteworthy that the boundaries of the lobes are not always formed by conspicuous sulci. The fifth or insular lobe is hidden within the depths of the lateral sulcus, and can be revealed when the *opercula* are removed. The sixth or limbic lobe, consists of the *parahippocampal gyrus*, *cingulate gyrus*, *subcollasal gyrus* and *para-terminal gyrus*, has grown acceptance. Additional, morphological and functional units have been suggested. These include the three lateral gyri of the temporal lobe (superior, middle and inferior temporal lobe), as well as the *central lobe* composed of the *pre-central* and *post-central gyri*, and the *para-central lobule*.[4,5]

Recent clinical advancements, including brain imaging or target specific procedures, has increased the demand for a more advanced understanding of the structure of the brain, by students and residents of neurology, neurosurgery and biological psychiatry, as well as basic neuroscientists. The current application of microneurosurgery is closely dependent upon using *sulci* on the brain's surface as primary landmarks or as surgical corridors for a growing number of new neurosurgical approaches.[6-8] The inherent variability of cortical function is confounded by the brain's neuroplasticity.[9] Cortical mapping, as part of the neurosurgeons current armamentarium, allows for specific functional sites on the brain to be determined, but does not negate the necessity for understanding the details of the surface and deep structures of the brain.[10,11] The need for a more sophisticated, functionally relevant understanding the structure of the brain has resulted in a surge of neuroanatomy dissection courses, including gross neuroanatomical observation, cross-sectioning, blunt dissection and various fiber dissection techniques.[12] The aim here is to provide a detailed, but easily applied, protocol for the study of the supratentorial anatomy of the human brain in cadaveric specimens, with relation to their each regions functional significance.

MATERIALS ANDMETHODS

Sixteen (16) adult, formalin fixed cerebral hemispheres were included in this study. Surface anatomy, blunt dissection of the lateral ventricles, and cross-sectioning of the anterior portion of the hemisphere, was performed on all specimens.

Observations of the surface anatomy and blunt dissection for observation of the deep structures are performed on either a whole brain specimen or a single hemisphere, right or left, from which the meninges and superficial blood vessels have been carefully removed. All specimens were formalin fixed in 10% formalin solution. The brainstem along with the cerebellum was removed from the cerebrum using a scalpel blade to cut through the superior end of the cerebral peduncle on each side. Ventrally, the cuts were caudal to the mammillary bodies and rostral to the oculomotor nerves. Dorsally, the cut was caudal to the pineal gland.

A long thin, brain knife, #10 blade scalpel, blunt tip forceps, pointed forceps, scissors (blades 3 cm or longer, blunt tip and pointed tip),a scalpel handle without a blade or a round tip spatula (about 5 mm wide), and blunt probe were used.

RESULTS

Topographical Anatomy of the Cerebral Cortex

Step 1: Identification of Primary Fissures and Sulci

Once the cerebrum has been stripped of meninges and blood vessels, the major sulci and fissures that serve to divide the brain into its primary lobes and functional regions can be delineated. The mid-sagittal, longitudinal or inter-hemispheric fissure incompletely separates the two hemispheres. The *fissure* is about 3-4 cm deep and contains the *falxcerebri*.

The *lateral sulcus* (*sylvian fissure*) is formed by temporalization, and is readily identifiable on the lateral surface. This is the deepest sulcus of the cerebrum, which lies mostly horizontal, separating the frontal and temporal lobes. The superior and inferior margins of the fissure, constitute the *frontoparietal* and *temporal opercula*, respectively, which cover the *insula*.[7] Clinically, the "perisylvian" cortex refers to neural regions important for the production and/or comprehension of spoken words. The *central sulcus (of Rolando)*, which separates the frontal and parietal lobes, extends superiorly from the longitudinal fissure and courses inferiorly and slightly anteriorly to the lateral sulcus. Its inferior end does not quite join the lateral sulcus, and its superior end extends a couple mm on the medial surface of each hemisphere. Below the central sulcus, just above the lateral fissure is the *inferior Rolandic point*.[7] The central sulcus is usually freestanding, without intersections, and serves as a landmark border to separate the primary motor area of the pre-central gyrus from the first somatosensory area of the postcentral gyrus. The *parietooccipital sulcus* is largely confined to the medial surface of the hemisphere. The *Calcarine sulcus*, a deep sulcus on the medial surface, courses from the *splenium* towards the occipital pole. The calcarine sulcus is an important landmark for the primary visual area.

Step 2: Identification of Primary Gyri and Sulci

The frontal lobe forms the largest and most anterior portion of the hemispheres, located anterior to the central sulcus and superior to the lateral sulcus. On the lateral surface, the *precentral sulcus* lies about 4.5 cm posterior to the *bregma*.[13] It marks the anterior end of the precentral gyrus and is often divided into two parts (superior and inferior). The agranular cortex of the precentral gyrus serves as the primary motor area (Brodmann area 4). The anteroposterior coursing *superior* and *inferior frontal sulci*, separate three large *gyri, superior, middle* (the largest) and *inferior frontal gyri*. The superior frontal gyrus is usually divided into two parts by the *medial frontal sulcus*. The medial lip of the superior front gyrus has also been referred to as the *medial frontal gyrus*.[2] In the majority of hemispheres (about 80-90%), the superior frontal sulcus intersects with the pre-central sulcus, forming the so-called "T-junction" or frontal eye field. This area is believed to control the voluntary scanning movements of the eye, independently of visual information. [Figure 1].

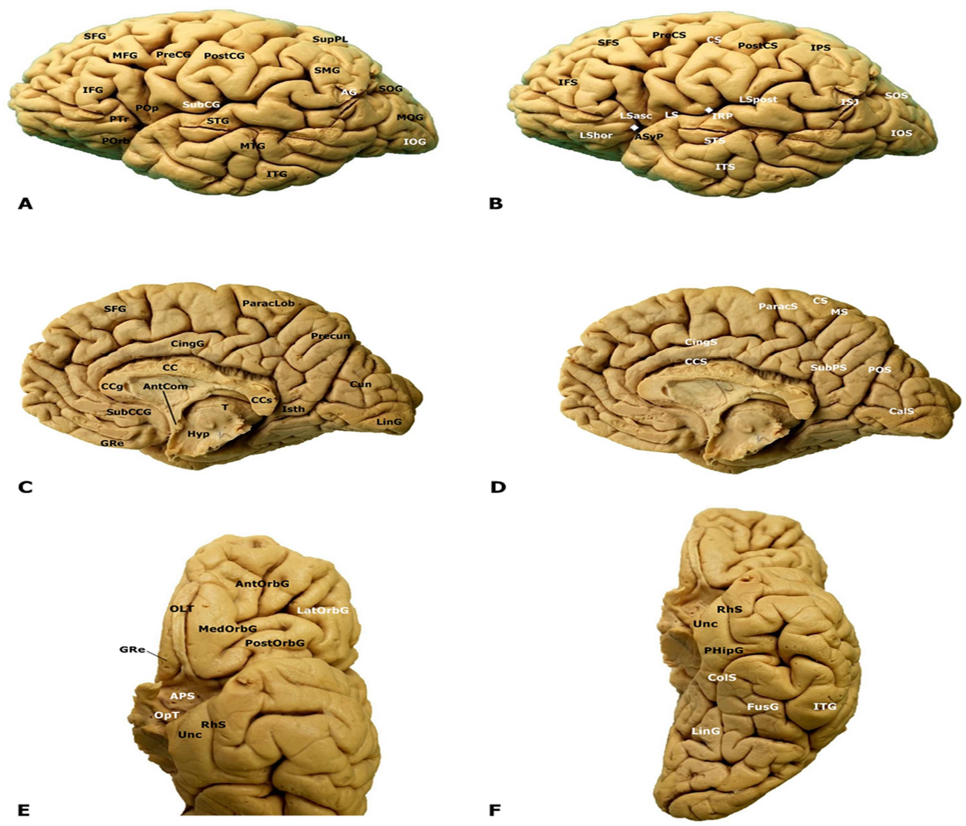

Figure 1:. Surface anatomy of the cerebral hemispheres, showing the gyri and sulci of the superolateral surface **(A,B)** medial surface **(C,D)** and basal surface **(E,F)**.***(Steps 1 and 2)***.AG: Angular gyrus; AntCom: Anterior commisure; ASyP: anterior sylvian point, CalS: Calcarine sulcus; CCS: Sulcus of Corpus Callosum; CingS: Cingulate sulcus; ColS: collateral sulcus; CC: Corpus callosum; CCg: Corpus callosum genu; CCs: spenium; CingG: Cingulate gyrus; CS: Central sulcus (of Rolando); Cun: Cuneus; FusG: Fusiform gyrus (or occipitotemporal gyrus), GRe: Gyrus Rectus (or Straight Gyrus), Hyp: hypothalmus; IFG: Inferior Frontal gyrus; IFS: Inferior Frontal sulcus; IOS: Inferior Occipital sulcus; IPS: IntraParietal sulcus; InfPL: Inferior Parietal Lobule;ITG: Inferior Temporal gyrus; ITS: Inferior Temporal sulcus; ISJ Intermediary sulcus of Jensen;IRP: Inferior Rolandic Point; Isth: Isthmus of the cingulate gyrus;LS: Lateral sulcus (of Sylvius); LSasc: Ascending ramus; LShor: Ascending Horizontal ramus; LSpost: Posterior ramus; LinG: Lingual Gyrus; MS: Marginal sulcus; MFG: Middle Frontal gyrus; MOG: Middle Occipital gyrus; OLT: olfactory tract; PHipG: ParaHippocampal gyrus; ParacLob: Paracentral lobule; ParsOp: Pars opercularis; ParsOrb: Pars orbitalis; ParsTr: Pars triangularis; POS: ParietOccipital sulcus; ParacS: Paracentral sulcus; PreCG: PreCentral gyrus; PreCS: PreCentral sulcus; Precun: Precuneus; SubCCG: Subcallosal gyrus; SFG: Superior Frontal gyrus; SFS: Superior Frontal sulcus; STS: Superior Temporal sulcus; SMG: SupraMarginal gyrus; STG: Superior Temporal gyrus; SubCG: subcentral gyrus; SubPS: SubParietal sulcus; SupPL: Superior Parietal Lobule; T: thalamus; Unc: Uncus.

The irregular, inferior frontal gyrus is divided on its inferior surface by small rami from the lateral fissure of Sylvius. From anterior to posterior, the *anterior horizontal* and *anterior ascending branches* of the lateral fissure into three regions, *pars orbitalis*, *pars triangularis* (*Broadman 45*) and *pars opercularis* (*Broadman 44*). The emergence of the two rami from the same point along the *lateral fissure*, gives shape to the pars triangularis. Anteriorly, the pars orbitalis is the largest part. The pars opercularis usually displays a "U" shape, with a more developed anterior portion, which is divided by another ramus of the lateral fissure, the *diagonal sulcus* of *Eberstaller*.[6] The *anterior Sylvian point* is an enlargement of the *lateral fissure*, which in most brains has a cisternal aspect.[8] It is a constant landmark, lying just inferior to the triangular part of the inferior frontal gyrus, and divides the lateral fissure into anterior and posterior branches.[6,8] Pars opercularis and triangularis form *Broca's motorspeecharea* for the formation of words, which is usually developed in the dominant (predominately left in 98%) hemisphere.[14,15] Broca's area is located between the *stephanion* and *pterion* of the skull, along the coronal suture.[13,16]

On the inferior (frontobasal or orbital) surface of the frontal lobe, the *olfactory sulcus*, holding the *olfactory tract* and *bulb* and the *straight gyrus*, which lies medially are easily identified. The "H" shaped orbital sulcus (*cruciformsulcus* of *Rolando*), divides the surface lateral to the olfactory sulcus into *medial*, *anterior*, *lateral* and *posterior orbital gyri*. These orbital gyri constitute a major part of the prefrontal cortex, involved in judgment and foresight. The olfactory tract can be followed towards the temporal lobe (the temporal pole can be dissected away for a clearer perspective) to identify the olfactory cortex laterally, and the *anterior perforated substance*, *diagonal band of Broca* and *optic tract*, respectively, medially.[16,17,18] The posterior orbital gyrus is just anterior to the anterior perforated substance (situated above the bifurcation of the internal carotid artery), and the is often connected medially to the medial orbital gyrus. The medial orbital gyrus connects to the anterior most area of the *insula* with the *transverse insular gyrus*.

The parietal lobe extends from the central sulcus, posteriorly to an imaginary line between the parieto-occipital sulcus and *preoccipital notch*, and inferiorly to the lateral fissure and its extension to the posterior border. On the lateral surface the post-central sulcus marks the posterior border of the post-central gyrus, about 6.5 cm posterior to the bregma.[13] The granular cortex of the post-central gyrus comprises the primary somatosensory cortex (Brodmann 3,1,2). On the superior surface of the hemisphere, the *ascending band* of the *cingulate* (*marginal sulcus*) serves as an important landmark for identifying the post-central gyrus.

The central sulcus does not intersect with the lateral fissure. The sub-central gyrus formed at the base of the central sulcus, connects the pre- and post-central gyri (gyral continuum) to form the central lobe, which morphologically is situated approximately at the median portion of the hemisphere. Hence, the central lobe is comprised of the pre- and post-central-gyri, the sub-central gyrus, and the para-central lobule. This is arguably the most eloquent area of the brain, corresponding to sensorimotor function.[4] The sub-central gyrus is located just below the inferior rolandic point and is also referred to as the *rolandic operculum* or the "*inferior frontoparietalplis de passage of Broca*".[7]

Frequently the post-central sulcus is divided into a superior and inferior part by the *intraparietal sulcus*, which originates about at the midpoint of the post-central sulcus. The *intra-parietal point* is defined by the point where the intra-parietal sulcus meets the post-central sulcus, and serves as a landmark for the underlying *atrium* of the *lateral ventricles*.[8]The intra-parietal sulcus courses horizontally, parallel to the longitudinal fissure and divides the parietal lobe into two lobules. The quandrangular, *superior parietal lobule* (association cortex) lies above the intra-parietal sulcus, and the *inferior parietal lobule* (*sensory speech area of Wernicke*) lies inferiorly. The parieto-temporal intersection lies just inferior to the later. The inferior parietal lobule formed by the *supra-marginal gyrus* (auditory area of speech) at the posterior end of the lateral fissure and the *angular gyrus* (visual area of speech) at the posterior end of the superior temporal lobe. The supra-marginal gyrus is a U-shaped gyrus that surrounds the distal end of the lateral fissure, and the angular gyrus caps the distal end of the horizontal branch of the *superior temporal sulcus*, the *angular sulcus*.[2] The *intermediate sulcus of Jensen* (the inferior vertical branch of the intra-parietal sulcus) runs between and separates supra-marginal and angular gyri.[19]In addition to the intermediate sulcus of Jensen, the intra-parietal sulcus usually gives off a second branch, the *transverse parietal sulcus of Brissaud*, a small, superior branch.

The *temporal pole* forms the anterior boundary of the *temporal lobe*. The posterior boundary is the line formed between the pre-occipital notch and the parieto-occipital sulcus, and the superior boundary is formed by the lateral sulcus and the imaginary line continuing to the posterior boundary.[17] Similar to the frontal lobe, the lateral surface of the temporal lobe is also compose of three horizontally distributed gyri; the *superior* and *inferior temporalsulci* divide the *superior*, *middle* and *inferior temporal gyri*. The temporal lobe is the most heterogenous region of the neo-cortex, and appears to serve three basic sensory functions; processing auditory input, visual object recognition and long-term storage of information. Because of its role in linking present sensory and emotional experience, it can be considered the integrator of sensations, emotions and behavior.

The well-defined superior temporal sulcus begins at the temporal pole. This deep and continuous sulcus terminates posterior to the end of the lateral (Sylvian) fissure (*posterior sylvian point*). At the posterior sylvian point, the superior temporal sulcus bifurcates into and ascending segment, the intermediate sulcus of Jensen, which separates the supra-marginal and angular gyri, and a horizontal segment, that is capped by the angular gyrus.[2,7,8] In contrast, the inferior temporal sulcus is usually discontinuous. The extensive superior surface of the superior temporal gyrus forms the temporal operculum of the lateral sulcus, which covers the inferior aspect of the insula. The inferior temporal gyrus (*lateral occipitotemporal gyrus*) extends posteriorly to the occipital lobe.

The inferior or basal surface of the temporal lobe is continuous with the inferior surface of the occipital lobe. The inferior temporal gyrus forms the lateral aspect of the inferior surface of the temporal lobe. The *fusiform* (or *lateral temporooccipital*) *gyrus* is bounded by the *temporooccipital* and *collateral sulci*, laterally and medially, respectively.

Gyri and sulci of the occipital lobe are fairly non-constant, although the superolateral surface tends to be comprised of three longitudinal gyri (superior, middle and inferior), horizontal to the inter-hemispheric fissure. On the lateral surface of the occipital lobe, the *superior occipital sulcus* (*intra occipital sulcus*[20] or *transverse occipitals sulcus*[2] is the posterior continuation of the inter-parietal sulcus. It serves as the boundary between the *superior occipital gyrus* and the *middle occipital gyrus*, which is more horizontally orientated.[2,6] The less-defined, *inferior occipital sulcus* (also referred to as the *lateral occipital sulcus*[2]), divides the middle and inferior occipital gyri. The *lunate sulcus*, when present, is usually situated vertically.

On the medial surface, the occipital lobe is composed of the *cuneal* and *lingual gyri*, which are separated by the calcarine fissure (the principal fissure).The emergence of the parieto-occipital sulcus divides the calcarine fissure into two parts, anterior and posterior. The anterior part of the calcarine fissure results in an elevation of the medial wall of the occipital horn of the lateral ventricle, the *calcaravis*. The posterior part of the calcarine fissure abuts the visual cortex. The inferior surface is contiguous with the inferior aspect of the temporal lobe.

In 1975, with the fourth edition of the Paris Nomina Anatomica, the limbic lobe was defined as an independent cerebral lobe.[21] Broca first coined the term limbic (latin for border or ring) to describe a chain of structures that formed a “C”-shaped continuum around the diencephalon.[22] Despite their apparent anatomical and functional diversity, the limbic structures have been attributed to the functions of memory, learning and emotions.[6,8,15,23] The *cingulate sulcus* is a prominent structure on the medial surface of the hemispheres as it courses around the *corpus callosum*, continuing inferiorly as the *subcallosal sulcus* and superiorly as the *marginal sulcus*, defining the *cingulated gyrus* inferiorly. The cingulate gyrus is bound inferiorly by the *callosal sulcus* and superiorly by the *cingulated sulcus*. Anteriorly, it starts just beneath the *rostrum*, curves around the *genu*, and as it courses posteriorly to the *splenium* of the corpus callosum, the cingulate narrows to form the *isthmus* and continues with the *parahippocampal gyrus*. The parahippocampal gyrus comprises the inferior half of the limbic lobe. The anterior portion of the parahippocampal gyrus curves medially, forming the *uncal sulcus*, and the medial surface of the gyrus bends superiorly, forming the *subiculum*. The parahippocampal gyrus, which functions both in olfaction and memory, lies lateral to the *hippocampal sulcus* medial to the collateral sulcus on the inferior surface of the temporal lobe. It is considered part of the limbic lobe.[3]The anterior end of the collateral sulcus is usually interrupted and continues with the *rhinal sulcus*. The cortical area medial to the rhinal sulcus is the *entorhinal area*. The *uncus* is located on the most anterior and medial part of the parahippocampal gyrus, and overlies the *amygdala* anteriorly, and the *parahippocampus* posteriorly.[24] Just anterior to the *apex of the uncus*, which faces medially, are the *ambient* (more inferior) and *semilunar gyri*, which are separated by the *semianular sulcus*. Posterior to the apex are three small *gyri* of the posterior segment, the *uncinate gyrus*, *Bandof Giacomini*, and *intralimbic gyrus*.[4,24,25] The isthmus or retrosplenial cortex is defined as the region of the gyral continuum formed at the posterior end of the parahippocampal gyrus and the posterior end of the cingulate gyrus.

In addition to the *cingulate*, the medial aspect of the hemispheres demonstrates the *paracentral lobule*, the cortex surrounding the central sulcus on the medial aspect of the hemisphere. *Precuneus* is located between the marginal sulcus and the parieto-occipital sulcus, and is the medial extension of the superior parietal lobule. The *cuneus* is the region of the occipital lobe posterior to the parieto-occipital sulcus.

Dissection of Ventricular System

Step 3: Exposure of the Anterior Horn and Body of the Lateral Ventricle

The dissection of the ventricular system is a simplified version based on the dissections of Heimer.[15] Once the corpus callosum has been identified on the medial surface, a brain knife is used to make thin sections through the dorsal supra-callosal part of the hemisphere. The *central sulcus* can be identified, with the aid of the surface anatomy. After a few slices, the "*precentral knob"* or *"inverted omega"*, is usually notable on the central sulcus. The pre-central knob is a reliable landmark for the motor hand area.[26] The *semioval center* is the white matter in the center, and consists of all fiber types, including commissural, projection and association fibers.

The superior surface of the corpus callosum is gradually exposed via serial horizontal sections, with care taken to preserve the roof of the lateral ventricle. The most inferior of these horizontal slices lies across the frontoparietal operculum, at the level of a line between the base of the pars triangularis and 2cm superior to posterior ramus of the lateral fissure.[27]To open a small window into the lateral ventricle, the thin roof of the lateral ventricle is identified using an index finger to gently palpate the exposed superior surface lateral to the semioval center. Oncean area that gives in to gentle pressure is identified, a #10 blade is used to cut a small window into the body of the lateral ventricle. The window can then be expanded carefully, in a step-wise fashion, anteriorly and posteriorly using small cuts with the blade. Dissecting away any remnants of the cingulate gyrus exposes the superior surface of the corpus callosum.

Once the ventricle has been opened, the head of the *caudate nucleus* can be observed in the lateral aspect of the anterior horn. The caudate nucleus can be followed posteriorly to the central part of the lateral ventricle, where the body forms the lateral wall of the ventricle. The *thalamus* forms the medial wall. The *choroid plexus*, which covers most of the thalamus, the flat fiber bundle of *crus fornicis* and the *thalamostriatevein* can also be observed. Horizontal slices with the brain knife are used to remove the superior aspect of the occipital lobes and expose the *occipital horns* of the lateral ventricle [Figure2].

Step 4: Exposure of the Temporal Horn of the Lateral Ventricle

Exposure of the insular surface anatomy is achieved by dissecting away the frontoparietal opercula with a #10 blade and making a semicircular cut. The frontoparietal operculum is comprised of the triangular and opercular parts of the frontal lobe, the sub-central gyrus (connects the pre- and post-central gyri, and the anterior portion of the supra-marginal gyrus, together which are located between the anterior horizontal ramus and the posterior ascending ramus of the lateral fissure.[6,7]The depth of the cut is guided by using fingers to lift the opercula upwards. Removal of the frontoparietal operculum, reveals the anatomy of the insula, as well as superior surface of the superior temporal gyrus, which is hidden in the depths of the lateral fissure.

In 1975, with the fourth edition of the Paris NominaAnatomica, the insula was defined as an independent cerebral lobe.[21]The insula consists of two surfaces, anterior and lateral. The anterior surface is hidden by the *fronto orbital operculum*, formed by the posterior orbital gyrus and the orbital aspect of the inferior frontal gyrus. The lateral surface is hidden by the fronto-orbital operculum formed by the inferior frontal gyrus (pars triangulars and opericularis), sub-central gyrus, and anterior part of the supra-marginal gyrus.[28]

The *circular sulcus of Reil*, marks the periphery of the insula, which because of the triangular shape of the insular surface, is often divided into three parts (*anterior*, *superior* and *inferior peri-insular sulci*.[28] Three *short gyri*, originating at the *insula apex* form the anterior portion of the insula. The deep structures correlated with this anterior half is the head of the caudate nucleas, Two *parallel long gyri*, form the posterior portion, which are correlated to the thalamus and body of the caudate nucleus.[6] The *insular pole* is formed by the *transverse* and *accessory insular gyri*, which originate from the insular apex.[28] The *transverse insular gyrus* interrupts the circular sulcus of Reil. *Insular* surface structures that can be appreciated include the *short* and *long gyri*, *insular pole*, *insular apex* and *limen insula*.[28,29]

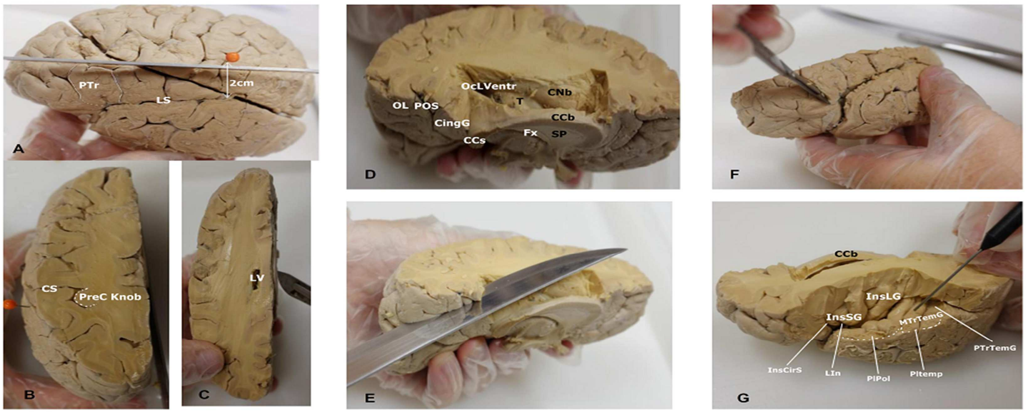

Figure 2: Exposure of the anterior horn and body of the lateral ventricle ***(Step 3).*****(A)** A brain knife is used to make thin sections through the supracallosal part of the hemisphere. The most inferior horizontal slice lies across the frontoparietal operculum, at the level of a line between the base of the pars triangularis and 2cm superior to posterior ramus of the lateral fissure. **(B)**The *"precentral knob"* or "*inverted omega"*, a reliable landmark for the motor hand area, can be located on the central sulcus after a few thin slices. **(C)** A small window is opened in the roof of the lateral ventricle**. (D)** The wind is gradually expanded anteriorly and posteriorly using small cuts with a #10 blade, exposing structures of the medial and lateral wall of the lateral ventricle. **(E)** Horizontal slices with the brain knife is used to remove the superior aspect of the occipital lobes and expose occipital horn of lateral ventricle. **(F)** In preparation of the next step, the frontoparietalopercula is dissected with a semicircular cut using a #10 blade. **(G)** Removal of the superior operculum of the insula, reveals the insular surface anatomy, and the structures of the extensive superior surface of the superior temporal gyrus. CaNb: Caudate Nucleus (body); CaNh: Caudate Nucleus (head); CS: central sulcus; CCb: Corpus Callosum (body); CCs: Corpus Callosum (splenium); CingG: Cingulate Gyrus;HeG: Heschl's Gyrus; InsLG: Insula Long Gyri; InsSG: Insula Short Gyri; InsCirS: Insula Circular Sulcus; LV: Lateral Ventricle; LS: Lateral Sulcus (of Sylvius); Lin: Limen Inulae; MTrTemG: Middle Transverse Temporal Gyrus; PTr: Pars Triangularis; PreC Knob: precentral knob; PTrTemG: Posterior Transverse Temporal Gyrus;Plpol: Planum Polare; Pltemp: Planum Temporal;T: Thalamus; OL: Occipital Lobe; SP: Septum Pellucidum; Fx: Fornix; OcLVentr: Occipital horn of the lateral ventricles; POS: parietoccipital sulcus

Exposure of the superior surface superior temporal gyrus is also achieved by dissecting away the frontoparietal opercula. The extensive superior surface of the superior temporal gyrus forms the temporal operculum of the lateral sulcus. The *anterior transverse temporal gyrus* (*Heschl's convolutions* or *gyrus*) is located anteriorly and forms the primary auditory area.[28] The inferior rolandic point corresponds to the anterior limit of the anterior transverse temporal gyrus.[7] The temporal opercular surface is divided into two planes: the *polar temporale* (anterior) and *planum temporale* (posterior). The planum temporale is comprised of the short transverse gyri, the *middle* and *posterior transverse gyri*. This is the auditory association cortex. In the left hemisphere it is also part of the receptive language area (Wernicke's area).[30]

The *temporal horn of the lateral ventricle* is located in the medial aspect of the temporal lobe. This horn of the lateral ventricle can be gradually exposed with small, step-by-step cuts using a #10 blade that are made along the superior temporal sulcus. Once the temporal horn has been exposed, the *hippocampus* and *choroid fissure* can be identified.[24,25,31] The floor of the *atrium* is formed by the *collateral trigon*. The latter is a result of the deep collateral sulcus. The *calcaravis*, formed by the calcarine sulcus, is located on medial wall of the posterior (occipital) horn. [Figure 3].

Step 5: Exposure of Midline Structures

Midline structures can be observed by exposing the *tela choroidea*. This can be achieved by a small transverse cut just behind the genu of the corpus callosum through the *septum pellucedum* to the *intra ventricular foramen of Monro*. Note that the *columns of the fornix* are transected. The bodies of the corpus callosum and fornix are pulled posteriorly, while dissecting the fornix from the choroid plexus. This will allow identification of: the crurafornices (diverge behind thalami, postero-laterally); the *hippocampal commissure* (transverse fibers between crurafornices);

thalamus; caudate nucleus, choroid plexus and choroidal vein; thalamostriate vein (covers caudate); *striaterminalis* (between caudate nucleus and thalamus); *internal cerebral veins*; and tela choroidea.[25] [Figure 4].

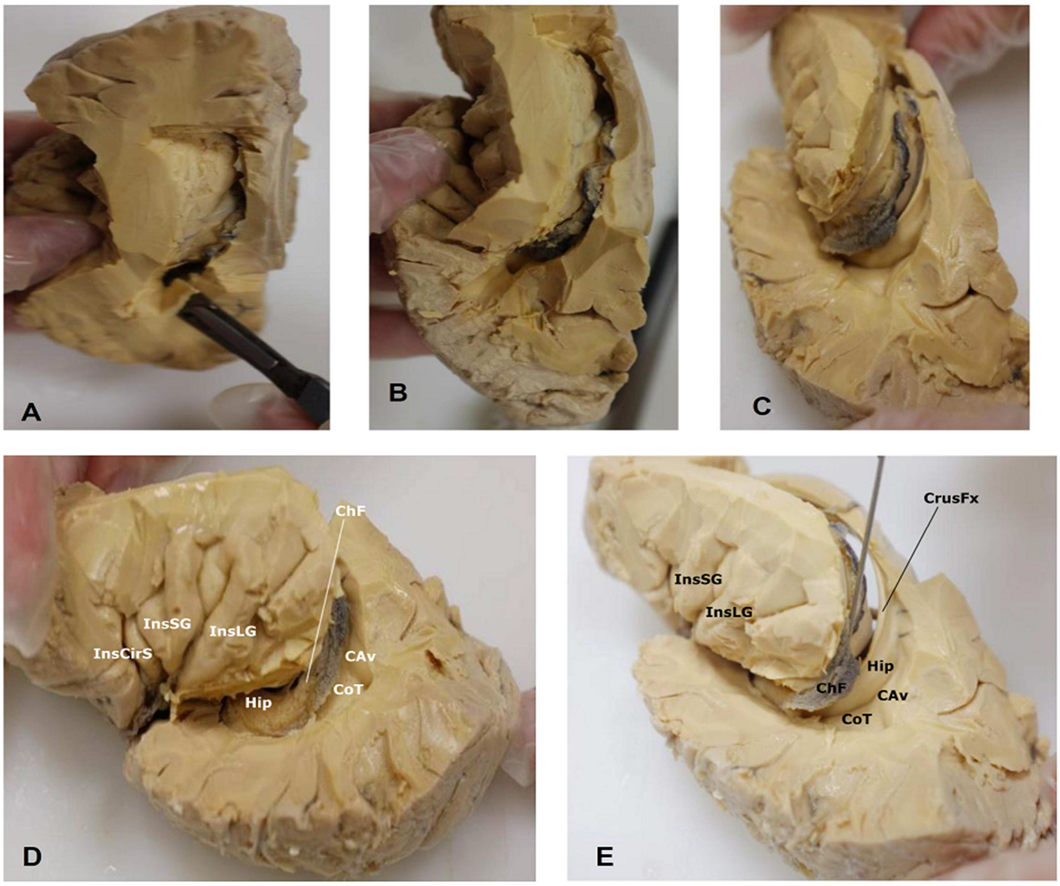

Figure 3: Exposure of the temporal horn of the lateral ventricle ***(Step 4).*** The temporal horn is gradually exposed with small, step-by-step cuts using a #10 blade first extending to the posterior aspect of the ventricular body **(A)**and then along the superior temporal sulcus**(B)**, until the hippocampus and fornix are fully visible **(C)**. Once the temporal horn has been exposed, anatomical details of the floor of the atrium can be examined **(D,E).**CAv: Calcar Avis; ChF: Choroid Fissure; CoT: Collateral Trigone; CrusFx: Posterior column of the Fornix; Hip: Hippocampus; InsSG: Insula Short Gyri; InsLG: Insula Long Gyri; InsCirS: Insula Circular Sulcus

Step 6: Dissection of Temporal Lobe

A horizontal cut made below the *lemun insula*, just anterior to the most rostral part of the hippocampus, allows the temporal lobe to be dissected away from the forebrain. This section is usually through the amygdala, and allows for a more detailed study of the structures of the limbic system and temporal lobe, including: crus fornicis, *fimbria hippocampi* (dorsal surface of hippocampus), parahippocampal gyrus, amygdala (in region of uncus), *dentate gyrus*, and collateral trigon.

The hippocampus, a primary part of the limbic lobe, consists of an intra ventricular prominence with the temporal horn of the lateral ventricle, and is referred to as Ammon's horn. The dentate gyrus lies laterally, and is separated from the subiculum by the hippocampal sulcus. With the ventricle, the hippocampus is covered by the *alveus*, a layer of efferent fibers that merge to give rise to the *fimbria*. The *fimbrio dentate sulcus*, separates the *dentate gyrus* and *fimbria*.[24] All of these structures together are defined as the *hippocampal formation*. [Figure 4].

Cross-Sectional Anatomy of the Forebrain

Step 7: Horizontal Sections to Examine Major Forebrain Nuclei

The remaining specimen, consisting of the anterior portion of the hemisphere, can be used to examine the forebrain nuclei and their relationship to the lateral ventricle and internal capsule. Initially the telachoroidea needs to be carefully removed from the dorsal surface of the thalamus using blunt forceps. The following can now be identified: striamedullaris (medial dorsal aspect of thalamus); *habenula*, *posterior commissure*, *superior colliculi* and *pulvinar of the thalamus*.

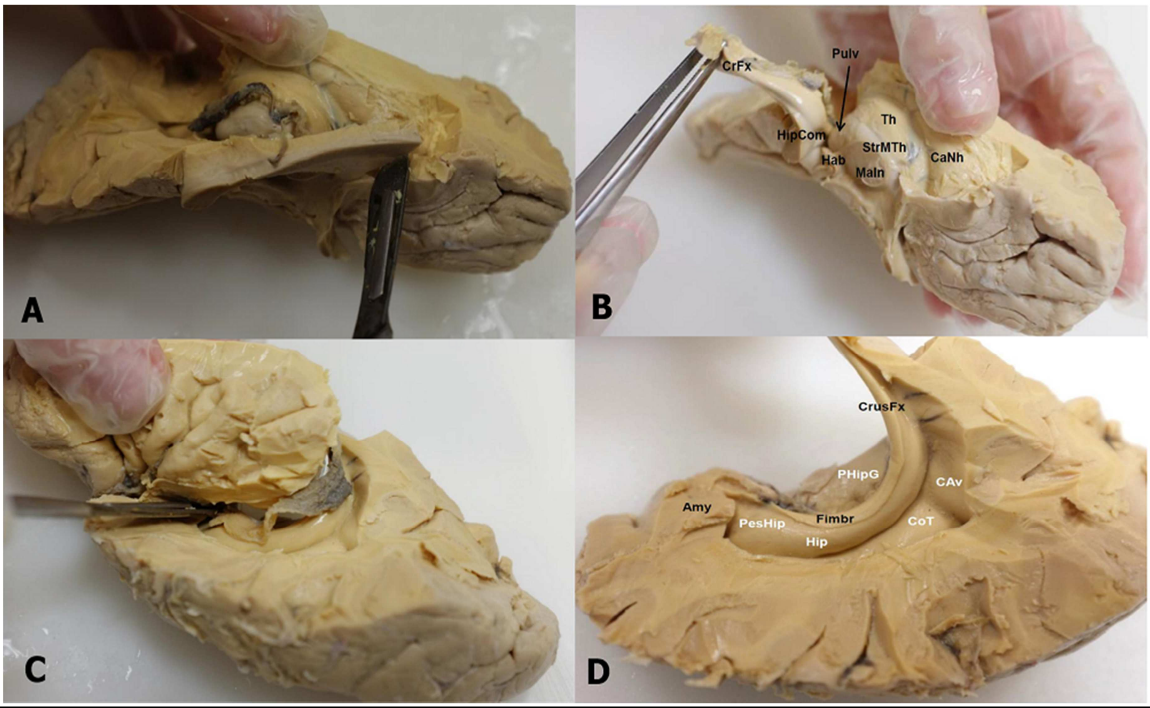

Figure 4: Exposure of the midline structures ***(Step 5)*** and dissection of the temporal lobe ***(Step 6)*****.(A)** The tela choroidea is exposed by a small transverse cut just behind the genu of the corpus callosum, transecting the columns of the fornix. **(B)** The bodies of the corpus callosum and fornix are pulled posteriorly, while dissecting the fornix from the choroid plexus. **(C)** To separate the temporal lobe, a horizontal cut is made below the *lemun insula*, just anterior to the most rostral part of the hippocampus. **(D)** This section is usually through the amygdala, and allows for a more detailed study of the structures of the limbic system and temporal lobe. Amy: Amygdala; CAv: Calcar Avis; CaNh: Caudate Nucleus (head);CoT: Collateral Trigone; CrFx: Crus Fornix;Fimbr: Fimbria Hippocampus; Hab: Habenula;Hip: Hippocampus,; HipCom: Hippocampal Commissure; MaIn: Massa Inter media;PesHip: Pes Hippocampus; Pulv: Pulvinar; PHipG: Parahippocampal Gyrus; StrMTh: Stria Medullaris Thalami; T: Thalamus.

A series of relatively thin horizontal sections (about 3 cm thick) made with a brain knife will the forebrain nuclei to be exposed. Differences in grey and white matter will depend on the length of time the brain has been formalin fixed. The first section will include the caudate nucleus, and may include the thalamus. The second section will give further details, showing the parts of the caudate nucleus and thalamus, as well as the *putamen* and *internal capsule*. The *anterior limb* of the *internal capsule* is comprised of the *frontal cortico point inetract* and *thalamic radiation*, while the *genu* and *posterior limb* contain *corticopontine fibers*, *cortico thalamic fibers* and *somatosensory radiation fibers*. The third section may allow identification of the interventricular foramen; column of the fornix (forms the ventral wall of the interventricular foramen); anterior horn of the lateral ventricle; *putamen*, *globus pallidus*, stria terminalis, *claustrum*, as well as the head and tail of the caudate nucleus. The next (fourth) horizontal slice should reveal the *anterior commissure*, fornix columns, thalamus, *inter-thalamic adhesion*, *striatum*, globus pallidus, *external capsule*, *extreme capsule*, claustrum, stria terminalis (between the pulvinar and caudate tail), and hippocampus. The last section is through the subcommissural part of the basal forebrain, which is exposes the *ventral striatopallidal system* (*ventral striatum*) and the *orbital frontal cortex*, indicated by the deep olfactory sulcus.[15]The ventral striatum reflects the region of the basal forebrain between the anterior perforated substance and the anterior commissure. Most structures in this region are difficult to observe in a gross brain preparation. Structures in this region include: *substantia innominata*, *ventral striatum*, *basal nucleus of Meynert* (*magno cellular nucleus*), *nucleus accumbens* (basal connection of the head of the caudate with the most anterior and inferior portion of the putamen) thalamus, globus pallidus, putamen, *bed nucleus* of the *stria terminalis* (located under the caudate head), claustrum, optic tract, pulvinar and tail of caudate nucleus. [Figure 5].

Figure5: Horizontal sections to examine major forebrain nuclei ***(Step 7)***.The remaining specimen, consisting of the anterior portion of the hemisphere **(A).** About 3cm thick horizontal sections are made with a brain knife. **(B)**The first section includes the caudate nucleus, and may include the thalamus. **(C)** The second section will further show the parts of the caudate nucleus and thalamus, and surrounding structures. **(D)** The fourth horizontal slice should reveal the *anterior commissure*. **(E)** The last section (fifth) is through the subcommissural part of the basal forebrain, exposing the ventral striatopallidal system. CL: Claustrum; CN: Caudate nucleus; CNh: caudate nucleus (head); CNb: caudate nucleus body; CNt: caudate nucleus tail; CA: cerebral aqueduct; CC: Corpus Callosum; CCb: Corpus Callosum (body); CCg: Corpus Callosum (genue); CCs: Corpus Callosum (splenium); CL: claustrum; EC: External capsule; ExC: extreme capsule; F: fornix; GP: globuspallidus; GPe: globuspallidusexternus; GPi: Globus pallidusinternus; InCtx: insular cortex; IC: internal capsule; ICg Internal capsule genu; ICal: internal capsule anterior limb; ICpl: internal capsule posterior limb; interventricular foramen IVF; ITAd: inter thalamic adhesion; 3V: third ventricle; MB: mammillary body; P: putamen; SubIn: Substansiainnominata

DISCUSSION

While the wide variation in the structure of sulci becomes apparent during a detailed gross morphological examination of the brain, the essence that the gyri of brain constitute a true continuum can be truly be appreciated. This strongly suggests that gyri should be appreciated as specific areas on the surface of the cerebral hemisphere, rather than as anatomically-defined separate entities.[6]

The simplified dissection method is proposed for training purposes. While it does not allow for an examination of all of the details of the brain, it provides an appreciation of the predominate structural pattern of the surface of the brain, in relation to the deep the structures. This appreciation is gained through the step-by-step dissection of the ventricular system and cross-sections, as described here. In addition to understanding the surface-to-deep relationships, the hands-on practical study of the anatomy of brain, allows the structural details to be appreciated from different angles, and ultimately offers a true understanding of the brain's three-dimensional structure.

CONCLUSION

Dissection methods described provide an appreciation of the predominate structural pattern of the surface of the brain in relation to the deep the structures. This appreciation is gained through the step-by-step dissection of the ventricular system and cross-sections. In addition to understanding the surface-to-deep relationships, the hands-on practical study of the anatomy of brain as described herein, allows the observer to gain a true three-dimensional structural understanding of the human brain.

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